DOCUMENT RESUME

ED 094 734 IR 000 932

AUTHOR Dansereau, Donald F.; And Others
TITLE Factors Relating to the Development of Optimal Instructional Information Sequences. AFHRL-TR-73-51(II). Final Report.
INSTITUTION Air Force Human Resources Lab., Lowry AFB, Colo. Technical Training Div.; Texas Christian Univ., Fort Worth. Inst. for the Study of Cognitive Systems.
REPORT NO AFHRL-TR-73-51(II)
PUB DATE Jul 74
NOTE 41p.; Final Report for Period April 1, 1973-December 31, 1973

EDRS PRICE MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS College Students; *Computer Assisted Instruction; Concept Teaching; Educational Research; Individual Differences; *Instructional Design; Instructional Innovation; *Intermode Differences; Multidimensional Scaling; Pictorial Stimuli; Training
IDENTIFIERS Aptitude Treatment Interaction; *INSCAL

ABSTRACT

INSCAL multidimensional scaling, an objective methodology for formulating effective technical information sequences for computer-assisted instruction, was shown to be of value with respect to defining the information complexity of technical material, developing sequences of key concepts within technical material, and providing an index of expert inter-rater consensus. When the INSCAL measure is obtained after student exposure to the material, INSCAL provides an indication of the correspondence between experts' and students' understanding of concept interrelationships. Major findings from the final phase indicated that: (1) alternative sequences of instructional material influenced student performance; (2) pictorial technical information sequences resulted in small performance differences when compared to verbal print sequences; (3) technical information difficulty debilitated student performance; (4) student reading aptitude was significantly related to student performance under both pictorial and verbal print presentation modalities; and (5) instruction sequences did not interact with student aptitude. (Author)

ED 094731

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

AIR FORCE HUMAN RESOURCES LABORATORY

AFHRL-TR-73-51 (II)

FACTORS RELATING TO THE DEVELOPMENT OF OPTIMAL INSTRUCTIONAL INFORMATION SEQUENCES

BEST COPY AVAILABLE

By

Donald F. Dansereau
Selby H. Evans
Tommie A. Actkinson
Gary L. Long

Institute for the Study of Cognitive Systems
Texas Christian University
Fort Worth, Texas 76129

TECHNICAL TRAINING DIVISION
Lowry Air Force Base, Colorado 80230

July 1974
Final Report for Period 1 April 1973 – 31 December 1973

Approved for public release; distribution unlimited.

BEST COPY AVAILABLE

IR000932

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by the Institute for the Study of Cognitive Systems, Texas Christian University, Fort Worth, Texas 76129, under contract F41609-73-C-0023, project 1121, with the Technical Training Division, Air Force Human Resources Laboratory (AFSC), Lowry Air Force Base, Colorado 80230. Dr. Gerard M. Deignan, Technical Training Division, was the contract monitor.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

MARTY R. ROCKWAY, Technical Director
Technical Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFHRL-TR-73-51 (II)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FACTORS RELATING TO THE DEVELOPMENT OF OPTIMAL INSTRUCTIONAL INFORMATION SEQUENCES		5. TYPE OF REPORT & PERIOD COVERED Final – 1 Apr to 31 Dec 73 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Donald F. Dansereau Gary L. Long Selby H. Evans Tomme A. Actkinson		8. CONTRACT OR GRANT NUMBER(s) F41609-73-C-0023
9. PERFORMING ORGANIZATION NAME AND ADDRESS Institute for the Study of Cognitive Systems Texas Christian University Fort Worth, Texas 76129		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 11210119
11. CONTROLLING OFFICE NAME AND ADDRESS HQ Air Force Human Resources Laboratory (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE July 1974 13. NUMBER OF PAGES 40
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Technical Training Division Air Force Human Resources Laboratory Lowry Air Force Base, Colorado 80230		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

instructional sequences	concept acquisition	instructional measurement
information organization	computer based training	
individual differences	multidimensional criteria	
inscal	pictorial information	
information complexity	instructional methods	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Inscal multidimensional scaling was shown to be of value with respect to (1) defining the information complexity of technical material, (2) developing sequences of key concepts within technical material, and (3) providing an index of expert inter-rater consensus. When the Inscal measure is obtained after student exposure to the material, Inscal provides an indication of the correspondence between experts' understanding of concept interrelationships and students' understanding of concept interrelationships. Major findings from the final phase indicated (1) alternative sequences of instructional material influenced student performance, (2) pictorial technical information sequences resulted in small performance differences when compared to verbal print sequences, (3) technical information difficulty debilitated student performance, (4) student reading aptitude was significantly

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20. (continued)

related to student performance under both pictorial and verbal print presentation modalities, and (5) instructional sequences did not interact with student aptitude.

BEST COPY AVAILABLE

Background

To be cost-effective, computer-based instruction must maximize student attainment of training objectives and offset computer costs through minimization of student training time to achieve each objective. The question of how complex technical information is best presented, in what form, and in what sequence, impact greatly upon the optimization of computer efficiencies for large numbers of students. Within computer based instructional systems, the effects of alternative instructional sequences upon student time to attain instructional objectives is important, but largely unknown. Traditionally, instructional sequences are based upon intuitive versus systematic scientific approaches. To expedite student progress, identification and validation of performance facilitating and debilitating instructional sequences must be determined if training time efficiencies are to be realized. Promising scientific methods are now available which allow complexity of technical information to be objectively measured, and subsequently modified to produce information content and sequences effective for students who vary in characteristics, e.g., aptitude level. A multivariate study was thus required to determine effects and interralationships among alternative instructional sequences, technical information difficulty levels, media presentation modalities and student aptitude levels upon multiple measures of performance.

Objectives were: to investigate the utility of an objective methodology (Inscal) for formulating effective technical information sequences; to test effectiveness of alternative instructional sequences in verbal and pictorial presentation modes; to determine if the effectiveness of instructional sequences varies as a function of the difficulty level of technical material; to determine if some instructional sequences are more performance-facilitating for low-aptitude students whereas other sequences are more effective for high-aptitude students; to determine effects of verbal print versus pictorial information sequences upon the performance levels of high- and low-aptitude students.

Approach

Technical materials (Structure of Matter and Oscilloscope Operations) were selected and determined to constitute significantly different difficulty levels. Inscal multidimensional scaling methodology was applied to 50 minute course segments by means of concept similarity ratings obtained from technical experts within the academic and military communities. Computer algorithms were developed to provide two different instructional sequences for each instructional package. Also, pictorial and verbal print material versions of each instructional package were generated. Measures of student performance for each instructional package included: (1) verbal print multiple choice tests, (2) pictorial multiple choice tests developed to correspond to verbal multiple choice tests, (3) Concept Cloze, as a measure of student comprehension of technical material covered, and (4) Student/Expert Understanding of

Concept Interrelationships, as a post-instructional measure of the degree to which student understanding of technical concepts corresponded to the experts' understanding of the interrelationships among technical concepts. High and low student aptitude classifications were assessed by the Delta Reading Vocabulary measure.

Findings and Conclusions

Instructional sequence alternatives developed from the Inscal method resulted in statistically significant but otherwise small student performance differences among the instructional sequences. Thus, how technical information is sequenced does contribute to subsequent student performance; however, the magnitude of these differences under the conditions of the present study was not great (less than 5% in student performance). Though media presentation modalities (pictorial versus verbal print) were found to be statistically significant, student performance differences were found to be marginal. Thus, the findings from the present study indicate no practical performance gains attributable to pictorial presentation as opposed to verbal print presentation for low-aptitude students as reported by other investigators.

Instructional sequencing alternatives were not found to interact with high or low student aptitude, media mode (pictorial versus print)or difficulty level of technical material. Hence, instructional sequences similar to those employed in the present study may not unduly influence the performance of students even if those students differ in aptitude.

Results of a four-way analysis of variance indicated that high scores on the Delta Reading Vocabulary aptitude measure performed substantially better on all dependent variables to include the pictorial multiple choice test than did low-aptitude students. Within the low-aptitude group, no evidence was found to support the contention that pictorial multiple choice tests result in better performance than verbal tests for low-aptitude students. Hence, it is unlikely that pictorial tests will substantially improve low-aptitude student performance.

In all conditions, males outperformed females on all performance measures. However, performance differences were primarily attributable to the difficulty factor inherent in the oscilloscope as opposed to the structure of matter technical material. Thus, if female technical trainees are to be increasingly assigned to courses where unfamiliar and difficult technical concepts are taught, student aptitude and motivational factors, e.g., interest, should be given greater consideration when technical materials are developed or revised.

In conclusion, the Inscal method of developing both improved measures of technical information complexity and performance-facilitating instructional sequences, also offers several other advantages. This objective method can be applied to new technical material at the time experts write it. Further, alternative instructional sequences can be tailored to the needs of subgroups of students in an individualized manner. Other benefits are discussed in the Conclusions section of this report.

PREFACE

The contributions of knowledge and time made by numerous individuals in the local communities, academic and military environs impelled the development and successful completion of the Phase II study. The leadership of Texas Christian University's Colonel Bearden (USA ROTC) and Lt. Colonel Reed (USAF ROTC) and University of Texas at Arlington's Lt. Colonel Weems (USAF ROTC) in the recruitment of the ROTC student subjects was of vital significance. Cooperation of the Hill County Junior College's (Cleburne, Texas) administration in encouraging student participation was deeply appreciated. In addition, the excellent combined coordination and cooperation of the Texas Christian Psychology Department faculty in providing the general psychology student subjects played an important role in completing the Phase II experimentation.

Noteworthy contributions were made by Dr. Gerald Deignan, Technical Training Division, Lowry AFB, Colorado by his constant involvement, deep concern and ready assistance in all areas of the research.

TABLE OF CONTENTS

	Page
PHASE II: THE MAIN EXPERIMENT	6
Method	7
Experimental Design	8
Figure 1 - Experimental Design	8
Subjects	8
Stimulus Materials	9
Dependent Measures	10
Individual Difference Measure	11
Procedure	11
Results	12
Scoring of the Dependent and Individual Difference Measures	12
The Four Way Analyses of Variance	13
Table 1 - Four Way Analyses of Variance: Group Proportion Means for Package Difficulty Factor	14
Table 2 - Group Means for the Main Effect of Presentation Mode on All Four Dependent Measures	15
Table 3 - Group Means for the Main Effect of Instructional Sequence on All Four Dependent Measures	16
Table 4 - Four Way Analyses of Variance: Group Means for the Interaction Between Delta Performance and Package Difficulty	17
Intercorrelations Among the Dependent and Individual Difference Measures	18
Table 5 - Average Intercorrelation Matrices for the Two Levels of the Package Difficulty Factor	19
Table 6 - Average Intercorrelation Matrices for the Two Levels of the Mode of Presentation Factor	20
Table 7 - Average Intercorrelation Matrices for the Three Levels of the Instructional Sequence Factor	21

Page

Two Way Analyses of Variance (Male/Females and Package Difficulty) 22
Table 8 - Two Way Analyses of Variance: Group Means for the Significant Interaction Between the Male/Female Factor and Package Difficulty 23
Two Way Analyses of Variance (Male ROTC/Male Non-ROTC) 23
Table 9 - Group Means for Male ROTC/Male Non-ROTC Factor on Each Dependent Measure 24

Discussion 25
The Impact of Instructional Sequencing 25
The Effect of Presentation Mode 27
The Role of Individual Differences 28
Effectiveness of the Dependent Measures 29

Summary and Conclusions 30

References 33

Annex A - Means and Standard Deviations for Each Experimental Condition on All Dependent Measures 34

PHASE II: THE MAIN EXPERIMENT

One of the major conclusions drawn from an analysis of previous investigations into the effects of instructional sequencing upon student performance is the inconsistency of the findings (AFHRL-TR-73-51 (I), Factors Related to Developing Optimal Instructional Sequences: Phase I). To summarize briefly, some studies have found that performance is apparently influenced by the particular sequence in which instructional material is presented, while others have not. The variety of procedures, stimuli, and response measures used in prior experiments has made it difficult to determine the conditions under which instructional sequencing is an important variable. However, two critical factors influencing the conflicting outcomes of these experiments have been identified:

(1) lack of systematic procedures for developing informational sequences, and

(2) minimal attention to individual differences in information processing styles and capacity.

The primary purpose of the present experiment was to incorporate solutions to these two difficulties in an assessment of the effects of instructional sequencing upon performance. Additionally, two variables thought to interact with the effects of sequence and with individual differences have been included in an attempt to delimit conditions which attenuate or enhance sequence effects. These two variables, difficulty of the instructional material and mode of presentation (verbal versus pictorial/graphic), are also of general importance in the design of instructional procedures.

Specifically, the main experiment has been designed:

(1) to investigate the utility of multidimensional scaling as a method for describing the information structure of Air Force instructional material and to

investigate its potential as a basis for forming effective instructional sequences. As a result of the pilot studies discussed in AFHRL-TR-73-51 (I), the previously cited Phase I report, two instructional sequences, algorithmically formed from multidimensional scaling solutions of similarity judgments by "experts" in the content areas, were selected for assessment in the main experiment along with the original Air Force sequences.

(2) to determine if interaction effects exist between information sequence requirements and a measure of intellectual ability. The principal measure of ability employed is the Delta Reading Vocabulary Test.

(3) to determine the effect of two modes of presentation, verbal and pictorial/graphic, on test performance, especially in interaction with informational sequences and individual differences.

(4) to assess the interaction of instructional material difficulty with other independent variables. Two Air Force instructional packages varying in difficulty have been selected for inclusion on the basis of pilot work reported in AFHRL-TR-73-51 (I).

(5) to investigate the utility of two new performance measures in the assessment of the impact of instructional manipulations. A modified version of the "cloze" procedure and a similarity judgment methodology were developed for use with the Air Force material. Discussion of these dependent measures, along with standard multiple choice tests, shall be elaborated upon in the subsequent section.

Due to the conflicting nature of the results of previous experiments on sequencing and due to the exploratory nature of this study, no specific hypotheses have been formulated.

Method

This section will be divided into subsections dealing with: experimental design, subjects, stimulus materials, dependent measures, individual difference measures, and procedure.

Experimental Design. A fully crossed, three factor, between-subjects design was employed in this experiment (see Figure 1). The three factors were: instructional sequence (three levels designated original, proximal, and non-proximal), mode of presentation (two levels designated verbal and pictorial/graphic), and instructional package difficulty (two levels designated Oscilloscope Operation and Characteristics of Matter). Fifteen subjects were included in each of the twelve cells of the design. This number of subjects was considered sufficient to allow for the investigation of the effects of individual differences in intellectual ability.

Mode of Presentation	Package Difficulty	Instructional Sequence		
		Original Air Force	Proximal	Non-Proximal
Verbal	Oscilloscope	15 Ss	15 Ss	15 Ss
	Characteristics of Matter	15 Ss	15 Ss	15 Ss
Pictorial/ Graphic	Oscilloscope	15 Ss	15 Ss	15 Ss
	Characteristics of Matter	15 Ss	15 Ss	15 Ss

FIGURE 1

Experimental Design

Subjects. One hundred and eighty college students served as subjects in this experiment. Due to lack of a sufficiently large homogeneous body of available subjects, it was necessary to recruit individuals from a variety of sources. The subject mix can be characterized as follows: 50 males from the Air Force and Army ROTC units at Texas Christian University and the University of Texas at Arlington, 72 males from general psychology classes at Texas Christian University and Hill County Junior College, and 58 females from general psychology classes at Texas Christian University. General Psychology students were given experimental credit as partial fulfillment of their course requirements, while ROTC students were paid at a rate of $2.00 per hour. These subjects were distributed as systematically

as possible across the experimental conditions in order to avoid biasing the treatment effects and in order to set up a basis for exploring the effects of individual differences on the dependent measures. Since the military may experience an influx of females in the future, male-female differences in this experiment will be of particular interest. In each cell of this experiment there were four to six females and nine to eleven males.

Stimulus Materials. Based on the pilot work discussed in AFHRL-TR-73-51 (I), two sets of Air Force instructional material, varying in difficulty of acquisition, were selected for inclusion in this experiment. These two sets were:

(1) Characteristics of Matter. (pages 1-22 of the document labeled Precision Measuring Equipment Specialist, D C Circuit Analyses Block II),

(2) Oscilloscope Operation. (pages 1-18 of the Maintenance Electronics Operation). The results of Pilot Study 2 indicated that the Oscilloscope Operation package led to significantly poorer performance on the dependent measures than did the Characteristics of Matter package.

The original Air Force instructional packages were in primarily verbal form. To investigate the effects of pictorial/graphic as well as verbal presentation, these packages were converted into primarily pictorial representation. Approximately seventeen key concepts were derived from each of the packages, and a concept by concept matching of the information was maintained between the verbal and pictorial/graphic modes. These packages were prepared in booklet form containing approximately one concept per page. Examples of these stimulus packages were presented in Annex A of the AFHRL-TR-73-51 (I).

Three instructional sequences were used in the present experiment: (1) proximal (2) non-proximal and (3) the original Air Force sequence. Sequence development was accomplished in two stages. First, information structures were derived for each of the two instructional packages by

the multidimensional scaling of similarity judgments made by six "experts" to all possible pairs of the seventeen key concepts. The coordinates of the concepts located in these derived information structures were then submitted to two computer based algorithmic procedures for producing instructional sequences. One algorithm produced sequences in which concepts highly related by the experts were located contiguously in the sequence (the proximal sequence). The second algorithm produced sequences in which concepts not highly related were located contiguously (the non-proximal sequence). Examples of the output of the algorithms are presented in Annex B of the Phase I Report.

Dependent Measures. Four dependent measures were used in this experiment, examples of which are presented in Annexes D and E of the AFHRL-TR-73-51 (I).

(1) Similarity or relatedness judgments (on a scale from 1 to 100) between all possible pairs of the key concepts. These judgments were compared with those produced by the six "experts" for each package.

(2) Sets of verbal multiple choice questions used by the Air Force in the assessment of student performance on the instructional packages.

(3) Pictorial/graphic versions of the sets of verbal multiple choice questions. These were created to provide a measure compatible to the pictorial/graphic presentation format.

(4) A concept cloze comprehension measure in which all occurrences of key concepts in the original Air Force text were replaced by letters used as a substitution code. The subjects' task was to match the code letters with the appropriate concepts presented previously during the instructional stage.

The standard cloze technique was not included in this experiment due to time constraints on the experimental sessions and due to the high intercorrelation (.76) found between the concept cloze and the standard cloze in Pilot Study 1.

Individual Difference Measure. All subjects were given the Delta Reading Vocabulary Test at the time of the experiment. This test serves as our primary measure of intellectual ability.

Procedure. The experiment was run in eight, two-hour experimental sessions with all twelve cells of the design being represented in each session. For each session, two experimenters and two separate classrooms were used. Because the length of the two instructional packages varied slightly, the subjects in the cells utilizing the Characteristics of Matter material were run in a separate room from those subjects receiving the Oscilloscope Operation package. Upon arrival to the experiment, subjects were assigned to one of the two rooms at random and then assigned to one of the six conditions existing under each level of the instructional package factor. Again, these latter assignments were done randomly within the constraints of the distributional requirements (see the discussion of the experimental subjects presented earlier).

Following assignments to conditions, the subjects were given a brief description of their task. Each subject then received a stimulus booklet which contained the instructional information in either verbal or pictorial/graphic form, and in one of the three sequences (original, proximal, or non-proximal) depending on the experimental condition assigned. The experimenter then paced the subjects through the booklets at a rate of 45 seconds per page (this presentation rate was selected on the basis of Pilot Study 1). If a subject finished studying a page before time was called he was instructed to think over previous material, but not to look elsewhere in his booklet.

Following the completion of the stimulus booklet, each subject was given the four dependent measures in an order which would minimize the transfer of content-specific information from one measure to the next. This order was: similarity judgments, pictorial multiple choice, verbal multiple choice, and concept cloze. Instructions for each of the measures were printed on the tests booklets. Each subject was allowed to proceed through these measures at his own rate.

After completing all of the response measures, each subject was given the Delta Reading Vocabulary Test. Completion of this test concluded the experimental session.

Results

The presentation of results will be subdivided into discussions of the following facets of the data analysis:

(1) Scoring of the dependent and individual difference measures,

(2) four way analyses of variance,

(3) intercorrelations among the dependent and individual difference measures,

(4) two way analyses of variance using male/female and type of instructional package as factors, and

(5) two way analyses of variance using ROTC/non-ROTC and type of instructional package as factors.

Scoring of the Dependent and Individual Difference Measures. Three of the dependent measures, the pictorial multiple choice, the verbal multiple choice, and the concept cloze were scored as proportion correct in order to form a basis for comparison across conditions which required a slightly different total number of responses. The Delta Reading Vocabulary test was also scored as proportion correct.

The similarity (or relatedness) judgments for each subject were correlated with the average judgments for the "experts" on the appropriate instructional package. These individual correlations then served as measures of the correspondence of the subject and expert views of the relationships between the key concepts. Presumably, the more a subject learned from the instructional material, the greater would be his correlation with the average "expert." This measure will be referred to in the remainder of the report as S/E Correlation.

The Four Way Analyses of Variance. A four way, between-subjects, fixed effect analysis of variance was performed on each of the four dependent variables. The factors included in these analyses were: (a) package difficulty (Characteristics of Matter versus Oscilloscope Operation), (b) mode of presentation (verbal versus pictorial), (c) instructional sequence (original versus proximal versus non-proximal), and (d) Delta Reading Vocabulary performance (high versus low). Levels of this last factor were formed by assigning the seven best performers on the Delta within a cell to the high group and the seven worst to the low group. The individual with median performance on the Delta was excluded from the analysis. Inclusion of this Delta Vocabulary factor in the analysis served to potentially reduce the amount of variance entered in the error term, thus improving the power of the analysis.

Rather than treat each of the analyses separately, the results for each factor on each dependent measure are presented contiguously. The means and standard deviations for each cell on each dependent measure are presented in the Annex A of this report.

The package difficulty factor led to significant results on all four dependent measures: pictorial multiple choice, $F(1,144 \text{ d.f.}) = 110.4$, $p < .001$; verbal multiple choice, $F(1,144 \text{ d.f.}) = 88.0$, $p < .001$; concept cloze, $F(1,144 \text{ d.f.}) = 102.5$, $p < .001$; S/E correlations, $F(1,144 \text{ d.f.}) = 58.0$, $p < .001$. The mean performance on the two packages for each dependent measure are presented in Table 1. Inspection of the means reveals that for all the dependent measures, except the S/E correlation, the Characteristics of Matter package led to better performance than did the Oscilloscope package. These findings are congruent with the results of our pilot work. The S/E correlation measure, however, reverses the above findings, with the Oscilloscope package leading to significantly larger average correlations than the Characteristics of Matter package.

TABLE 1

Four Way Analyses of Variance: Group Proportion Means for Package Difficulty Factor
(proportion correct except where indicated)

Dependent Measures	Package Difficulty	
	Characteristics of Matter	Oscilloscope Operation
Pictorial Multiple Choice*	.778	.548
Verbal Multiple Choice*	.800	.589
Concept Cloze*	.845	.549
Subject/Expert Correlations*	.130 (average correlation)	.266 (average correlation)

N = 84 Ss per condition
* $p < .001$

This last result is probably due to the greater richness of relationships among the Characteristics of Matter concepts. These are basic physics concepts and many of the actual relationships were not explicit in the instructional material. It is possible that the "experts", having had more physics training, were basing their judgments on relationships not directly available in the instructional material. Also, since most of the subjects had some prior training in elementary physics, their judgments may have been biased by prior knowledge. On the other hand, the Oscilloscope package appeared to explicitly contain the majority of possible relationships between concepts, thus putting the subjects and "experts" on a common ground. With this package a more valid assessment of subject-"expert" correspondence seemed to be achieved. Differences between packages on the S/E Correlation Measure were probably spuriously generated by differences in relational richness rather than package difficulty.

The mode of presentation factor was found to be marginally significant with the pictorial multiple choice measure ($F(1,144$ d.f.) = 3.5, $p < .075$) and nonsignificant with the three other dependent measures. With pictorial multiple choice, the pictorial presentation mode led to better performance than verbal presentation (see Table 2).

TABLE 2

Group Means for the Main Effect of Presentation Mode on All Four Dependent Measures
(proportion correct except where indicated)

Dependent Measures	Mode of Presentation	
	Pictorial/Graphic	Verbal
Pictorial Multiple Choice*	.684	.642
Verbal Multiple Choice	.705	.686
Concept Cloze	.715	.700
S/E Correlations (Average Correlation)	.211	.188

N = 84 Ss per cell
* $p < .075$

Inspection of the means in Table 2 indicates that, although not significant, the level of performance with the Pictorial/Graphic mode of presentation was higher on each of the remaining dependent measures. Since the Verbal Multiple Choice, Concept Cloze, and S/E Correlation measures are in a verbal format, perhaps the failure to achieve statistical significance with these measures is due to difficulties encountered by subjects in translating the Pictorial/Graphic information into a format compatible with the verbally based dependent measures. This notion will be explored further in the Discussion section of this report.

The instructional sequence factor was significant with the Verbal Multiple Choice measure ($F(2,144$ d.f.) = 3.6, $p < .05$) and nonsignificant with the three remaining dependent variables. The group means are presented in Table 3. As can be seen, except for the S/E Correlation measure, the Proximal sequence generally results in slightly better performance than the other two sequences.

A Scheffe' post hoc analysis on the Verbal Multiple Choice measure revealed that the Proximal was significantly different from the Non-proximal at the .05 level and that other differences between means were nonsignificant.

TABLE 3

Group Means for the Main Effect of Instructional Sequence on All Four Dependent Measures (proportion correct except where indicated)

Dependent Measures	Sequence		
	Air Force Original	Proximal	Non-Proximal
Pictorial Multiple Choice	.663	.670	.656
Verbal Multiple Choice*	.698	.730	.658
Concept Cloze	.685	.712	.687
S/E Correlations (Average Correlation)	.214	.196	.188

N = 56 Ss per cell
* $p < .05$

Potential reasons for the lack of statistical significance with the Concept Cloze and S/E Correlation dependent measures on the instructional sequence factor can be cited. First, the previously discussed difficulties with the S/E Correlations and the Characteristics of Matter package would serve to reduce sensitivity to instructional sequence. Second, inspection of the Concept Cloze test showed than in some conditions the sensitivity of this measure was being attenuated by "ceiling effects"; a number of subjects were scoring 100% on this test with the Characteristics of Matter instructional material. The failure of the Pictorial Multiple Choice measure to reflect significance, however, does not seem to be attributable to difficulties with the measure. Obviously, further empirical exploration is necessary.

Significant differences due to the Delta Reading Vocabulary performance factor were found for each of the four dependent measures (Pictorial Multiple Choice, $F(1,144 \text{ d.f.}) = 38.3$, $p < .001$; Verbal Multiple Choice, $F(1,144 \text{ d.f.}) = 31.0$, $p < .001$; Concept Cloze, $F(1,144 \text{ d.f.}) = 52.8$, $p < .001$; S/E Correlations, $F(1,144 \text{ d.f.}) = 15.0$, $p < .001$). Inspection of the performance means revealed that with all dependent variables the high scoring Delta subjects performed better on the dependent measures than the low scoring Delta subjects.

The only interaction effect reaching significance in the four way analyses was package difficulty by Delta performance. This effect was significant with the S/E Correlation measure ($F(1,144 \text{ d.f.}) = 8.8$, $p < .005$) and nonsignificant with the three other dependent variables. The means representing the interactions are presented in Table 4. As can be seen the significant difference between high and low Delta on the S/E Correlation measures is primarily due to performance on the Oscilloscope Operation package. This finding adds further evidence to the previously discussed notion that the S/E Correlations are only valid with the Oscilloscope material.

TABLE 4

Four Way Analyses of Variance: Group Means for the Interaction Between Delta Performance and Package Difficulty

	Pictorial Multiple Choice (Proportion Correct)	
	Characteristics of Matter	Oscilloscope Operation
High Delta Performers	.858	.604
Low Delta Performers	.698	.493

N = 42 Ss per Cell

	Verbal Multiple Choice (Proportion Correct)	
	Characteristics of Matter	Oscilloscope Operation
High Delta Performers	.881	.633
Low Delta Performers	.718	.549

N = 42 Ss per Cell

TABLE 4 (Cont.)

	Concept Cloze (Proportion Correct)	
	Characteristics of Matter	Oscilloscope Operation
High Delta Performers	.934	.671
Low Delta Performers	.756	.418

N = 42 Ss per Cell

	S/E Correlation (Average Correlation)*	
	Characteristics of Matter	Oscilloscope Operation
High Delta Performers	.139	.328
Low Delta Performers	.123	.206

N = 42 Ss per Cell
* $p < .005$

Intercorrelations Among the Dependent and Individual Difference Measures. The intercorrelations among performances on the four dependent measures and the Delta Reading Vocabulary test were calculated for each of the twelve cells of the three factor design. Crude averages of these correlations were then calculated to produce intercorrelation matrices for each level of each factor.

The average intercorrelation matrices for the two instructional packages are presented in Table 5. Inspection of these matrices reveals a number of things. First, the correlations of the S/E Correlation measure with the other dependent variables are negligible for the Characteristics of Matter package but moderate for the Oscilloscope material, again supporting the notion of differential sensitivity of this measure across packages. Second, the intercorrelations among the other three dependent measures are higher with the Characteristics of Matter package than with the Oscilloscope material. The greater difficulty of the Oscilloscope package may have led to a larger degree of random responding, thus attenuating the correlations. Finally, with the exception of the S/E Correlation measure, the correlations between the Delta and the other three dependent variables range from .35 to .60, with no large, consistent differences between packages.

TABLE 5

Average Intercorrelation Matrices for the Two Levels of the Package Difficulty Factor

CHARACTERISTICS OF MATTER

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.84**	1.0			
Concept Cloze	.74**	.69**	1.0		
Subject/Expert Correlations	- .01	.06	.06	1.0	
Delta Reading Vocabulary	.55**	.60**	.49**	.07	1.0

N = 84 Ss
** $p < .01$

OSCILLOSCOPE OPERATION

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.35**	1.0			
Concept Cloze	.60**	.36**	1.0		
Subject/Expert Correlations	.30**	.35**	.65**	1.0	
Delta Reading Vocabulary	.35**	.36**	.54**	.35**	1.0

N = 84 Ss
** $p < .01$

The average intercorrelation matrices for the levels of the mode of presentation factor are presented in Table 6. The main discrepancy of interest between these two matrices involves correlations with the Delta Reading Vocabulary. (The matrices also show differences in the S/E Correlation measure, but the difficulties

with this measure have already been discussed.) The correlations between the dependent variables and the Delta are substantially larger with verbal presentation than with pictorial. This difference makes sense in that a measure of verbal ability, such as the Delta, should be more predictive in a verbal test than in a pictorial. Presumably, if we had included a measure of spatial/pictorial ability, the reverse finding would have occurred.

TABLE 6

Average Intercorrelation Matrices for the Two Levels of the Mode of Presentation Factor

PICTORIAL PRESENTATION

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.61**	1.0			
Concept Cloze	.73**	.60**	1.0		
Subject/Expert Corr.	.26**	.32**	.49**	1.0	
Delta Reading Vocabulary	.38**	.43**	.46**	.25*	1.0

N = 84 Ss
* $p < .05$
** $p < .01$

VERBAL PRESENTATION

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.58**	1.0			
Concept Cloze	.62**	.46**	1.0		
Subject/Expert Corr.	.02	.09	.22*	1.0	
Delta Reading Vocabulary	.51**	.53**	.57**	.17*	1.0

N = 84 Ss
* $p < .05$
** $p < .01$

The average intercorrelation matrices for the instructional sequence factor are presented in Table 7. These matrices appear to be very similar to one another with no compelling discrepancies.

TABLE 7

Average Intercorrelation Matrices for the Three Levels of the Informational Sequence Factor

ORIGINAL AIR FORCE SEQUENCE

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.65**	1.0			
Concept Cloze	.71**	.60**	1.0		
Subject/Expert Correlations	.15	.22	.42**	1.0	
Delta Reading Vocabulary	.47**	.52**	.60**	.23*	1.0

N = 56 Ss
* $p < .05$
** $p < .01$

PROXIMAL SEQUENCE

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.62**	1.0			
Concept Cloze	.65**	.51**	1.0		
Subject/Expert Correlations	.02	.05	.34**	1.0	
Delta Reading Vocabulary	.55**	.46**	.54**	.18	1.0

N = 56 Ss
* $p < .05$
** $p < .01$

NON PROXIMAL SEQUENCE

	Pictorial	Verbal	Concept	S/E Corr.	Delta
Pictorial Multiple Choice	1.0				
Verbal Multiple Choice	.51**	1.0			
Concept Cloze	.65**	.48**	1.0		
Subject/Expert Correlations	.25*	.36**	.30*	1.0	
Delta Reading Vocabulary	.34**	.47**	.41**	.22	1.0

N = 56 Ss
* $p < .05$
** $p < .01$

Two Way Analyses of Variance (Males/Females and Package Difficulty). A two-way, between subjects, fixed effects analysis of variance was calculated for each of the four dependent measures with males (122 subjects) / females (58 subjects) and Package Difficulty as the factors. Rather than treat each of the analyses separately, the results for each factor on each dependent measure will be presented contiguously.

As with the four-way analyses of variance the main effect of package difficulty was significant on all four dependent measures at the .001 level. The Characteristics of Matter package lead to better performance than the Oscilloscope instructional material.

The Male/Female main effect was significant with all four dependent measures (Pictorial, Multiple Choice, $F(1,176$ d.f.) = 3.8, $p < .075$; Verbal Multiple Choice, $F(1,176$ d.f.) = 5.3, $p < .025$; Concept Cloze, $F(1,176$ d.f.) = 7.5, $p < .01$; S/E Correlations, $F(1,176$ d.f.) = 22.4, $p < .001$). Inspection of the means indicates that in all cases the males performed at a higher level than the females.

The interaction between Male/Female and Package Difficulty was significant on all of the dependent measures except the Verbal Multiple Choice test (Pictorial Multiple Choice, $F(1,176$ d.f.) = 4.2, $p < .05$; Concept Cloze $F(1,176$ d.f.) = 12.3, $p < .001$; S/E Correlations, $F(1,176$ d.f.) = 12.8, $p < .001$. The means involved in these significant interactions are presented in Table 8. As can be seen from the table, the differences between males and females is in performance on the Oscilloscope material. Again, it should be noted that the S/E Correlation measure is sensitive to differences with the Oscilloscope instructional material.

TABLE 8

Two Way Analyses of Variance: Group Means for the Significant Interaction Between the Male/Female Factor and Package Difficulty

PICTORIAL MULTIPLE CHOICE**

	Characteristics of Matter	Oscilloscope Operation
Males	.793 (N = 57 Ss)	.568 (N = 65 Ss)
Females	.752 (N = 33 Ss)	.497 (N = 25 Ss)

** $p < .05$

VERBAL MULTIPLE CHOICE

	Characteristics of Matter	Oscilloscope Operation
Males	.822 (N = 57 Ss)	.595 (N = 65 Ss)
Females	.762 (N = 33 Ss)	.565 (N = 25 Ss)

CONCEPT CLOZE*

	Characteristics of Matter	Oscilloscope Operation
Males	.853 (N = 57 Ss)	.592 (N = 65 Ss)
Females	.832 (N = 33 Ss)	.436 (N = 25 Ss)

* $p < .001$

SUBJECT/EXPERT CORRELATIONS*

	Characteristics of Matter	Oscilloscope Operation
Males	.137 (N = 57 Ss)	.299 (N = 65 Ss)
Females	.118 (N = 33 Ss)	.180 (N = 25 Ss)

* $p < .001$

Two Way Analyses of Variance (Male ROTC/Male Non-ROTC). A two-way, between subject, fixed effects analysis of variance was performed on each of the four dependent measures with Male ROTC (50 subjects)/ Male Non-ROTC (72 subjects) and Package Difficulty as the factors. Again, the results for each factor on each dependent measure will be presented contiguously.

As expected the effect of package difficulty was again significant at the .001 level on all four dependent measures.

The effect of the Male ROTC/Male Non-ROTC factor was significant with the Pictorial Multiple Choice ($F(1,118$ d.f.) = 8.8, $p < .005$) and the Verbal Multiple Choice ($F(1,118$ d.f.) = 5.3, $p < .025$) and was nonsignificant with the Concept Cloze and the S/E Correlations. Inspection of the significant means (Table 9) reveals that the ROTC males performed at a higher level than the Non-ROTC males. The interaction effects was nonsignificant with all dependent measures.

TABLE 9

Group Means for Male ROTC/Male Non-ROTC Factor on Each Dependent Measures
(Proportion Correct Except Where Indicated)

Dependent Measure	MALE ROTC N = 50	MALE NON-ROTC N = 72
Pictorial Multiple Choice**	.699	.655
Verbal Multiple Choice*	.719	.703
Concept Cloze	.735	.698
S/E Correlations (average correlation)	.236	.211

* $p < .025$
** $p < .005$

Very little weight should be given to the finding of significant differences between ROTC and Non-ROTC males for two reasons. First, the distribution of individuals from these two categories over experimental treatments was relatively uneven (due to constraints of the experimental situation). Thus, treatment effects would naturally confound these differences. Second, the motivational level of the two categories of subjects may have varied due to the military nature of the experiment.

Discussion

The discussion of results will be divided into four sub-sections dealing with the following topics: the impact of instructional sequencing, the effect of presentation mode, the role of individual differences, and the effectiveness of the dependent measures.

Before proceeding with the discussion it is important to point out that a number of other analyses including analyses of covariance, were performed on the data. Because these analyses provided information that was redundant to the reported results, they are not presented in this document.

The Impact of Instructional Sequencing. The primary purpose of this research was to study instructional sequencing in a context which resolved some of the difficulties cited in the literature review and synthesis (AFHRL-TR-73-51 (I). In particular, the aim was to study the effects of objectively derived sequences (multidimensional scaling methods) and their interaction with individual difference variables and other meaningful instructional manipulations. The result of the four way analyses of variance indicated that a main effect composed of three different instructional sequences was significant with the Verbal Multiple Choice Measure and that all other interactions involving this factor were nonsignificant.

In addition, inspection of the means (Table 3) associated with the main effects on the other three dependent measures indicated that, in general, as with the Verbal Multiple Choice test, the proximal sequences (generated by the multidimensional scaling methods) led to better performance than the other two sequences.

As stated in the presentation of results, the failure of the main effect of three instructional sequences to reach significance on the other dependent variables is partially explainable in terms of the present shortcomings of these other measures. The Concept Cloze led to skewed results (ceiling effects) with the Characteristics of Matter package, thus reducing its sensitivity to differences in performance. Further, the S/E Correlation variable has been shown to be insensitive to performance differences with the Characteristics of Matter material. This finding will be discussed more thoroughly in the sub-section entitled: The Effectiveness of the Dependent Measures.

Although one cannot be certain, it seems that the lack of correspondence among dependent measures with the instructional sequencing variable is not due to a spurious effect shown with the Verbal Multiple Choice variable, but rather to the relative insensitivity of the remaining measures (remember that the direction of differences between means was similar for all measures except the S/E Correlation). It should be noted that the Verbal Multiple Choice Measure contains the sets of questions originally used by the Air Force in testing acquisition of the instructional materials. Presumably this measure has been examined much more thoroughly for reliability and validity than the three other prototype measures especially constructed for this experiment.

Post hoc analysis of the effect of instructional sequencing with the Verbal Multiple Choice Variable indicated that the Proximal sequence derived from the multidimensional scaling method led to significantly better performance than the Non-Proximal Sequence. Inspection of the means revealed that the Original Air Force Sequence produced a level of student performance which fell between the Proximal and Non-Proximal sequences. The lack of larger differences in mean performance between the proximal and original Air Force Sequence conditions is not surprising. First, the original Air Force sequences have undergone revisions based on prior instructional experiences (revisions of some of this material probably occurred even prior to incorporation of these packages by the Air Force). These sequences are now undoubtedly close to being optimal for performance effective instruction. In fact, the actual sequence differences between the proximal and the original were quite subtle, therefore limiting potential performance differences. However, with newer instructional material (that is, material that has not been heavily revised based on instructional experience) it would be expected that the proximal sequence generated by the objective multidimensional scaling approach would lead to substantially better performance than a sequence generated by subjective means.

A second reason for the small performance differential in favor of the proximal sequence is the size of the instructional unit treated in this experiment. Due to pragmatic constraints, only about 30-40 minutes of instructional material could be presented. It is probably true that the impact of

sequencing is much stronger over larger units of instruction. The multidimensional scaling method can be applied to all levels of instruction from the overall curriculum to a particular course to a specific lesson. If there are performance differences in favor of this method with small units of instruction then these differences should be amplified with larger units.

Even if the objective multidimensional scaling method proves only equal in educational effectiveness to the present subjective techniques used by curriculum designers, the method may well offer advantages in efficiency, replicability, and control. With subjective techniques, the resulting sequence depends heavily on the skill of the individual designer, while the objective sequencing method permits the views of a large number of "experts" to be combined at a very small cost. Because the latter method is objective and allows for the pooling of a number of opinions, costly checking and re-checking of the effectiveness of instruction may be dramatically reduced.

The lack of significant interaction between instructional sequence and variables representing both individual differences and other instructional manipulations (for example, mode of presentation and package difficulty) may be most likely due to one of two reasons. First, the dependent measures employed may not have been sufficiently sensitive to detect such effects. Second, with the sets of instructional materials employed in the present study, it may be true that such interaction effects do not exist at a detectable level. In either case, further studies should be undertaken using a wider range of instructional material (especially material that has a wide range of a priori familiarity associated with it) and a greater variety of dependent measures.

The Effect of Presentation Mode. The results of the four way analyses of variance indicated that with the Pictorial Multiple Choice test Pictorial/Graphic presentation leads to significantly better performance than Verbal presentation (marginally at the .075 level). Although this main effect did not reach significance with the other three dependent measures, inspections of the means in Table 2 reveals general agreement among the measures with regard to the direction of mean differences.

Perhaps the failure of the other measures to reach significance was due to the difficulties on the part of the Pictorial/Graphic presentation groups in translating the learned material into the verbal format required by the Verbal Multiple Choice, Concept Cloze, and S/E Correlation measures. In any case, the very tentative conclusion that the Pictorial/Graphic mode of presentation leads to better performance than the Verbal mode requires further exploration and delimitation in the context of a variety of instructional materials.

The Role of Individual Differences. Besides their potential interaction with instructional sequence, individual differences are of general importance in the context of instruction. In this study three sources of individual differences were examined: performance on the Delta Reading Vocabulary test, sex, and ROTC affiliation. As mentioned in the presentation of results, the effects of ROTC affiliation were potentially confounded by differential motivational properties of the task for various classes of individuals and distributional imbalances across the experimental treatment groups. Because of these difficulties there will be no further discussion of this effect.

The results of the four-way analyses of variance indicated that high scorers on the Delta measure performed substantially better on all dependent variables than did low scorers. The one significant interaction involving Delta was with package difficulty on the S/E Correlation measure. As stated previously, this effect is probably due to the differential sensitivity of this dependent measure with the two levels of instructional material rather than a true interaction between Delta and package difficulty.

The intercorrelations between Delta and the dependent measures generally fell between .35 and .60. These correlations were somewhat higher for the verbal mode of presentation and somewhat lower for pictorial presentation. Since the Delta is a paper and pencil test requiring only 10 minutes for administration, it would appear to have substantial value as a device for selecting students and as a device for determining the sequence and pace or rate of instruction. This would be especially true for verbal materials.

The analysis of male/female differences in performance generally indicated a large difference in favor of the males on the Oscilloscope Operation package and a substantially smaller difference also in favor of the males, on the Characteristics of Matter material. The Oscilloscope Operation package led to significantly worse performance than the Characteristics of Matter on all dependent measures. The difficulty of this package and the relatively unfamiliar scientific concepts involved may have caused the greater differential between males and females due to a priori differences in scientific interest and ability. Such differences should certainly be taken into account in the design of future instructional programs.

Effectiveness of the Dependent Measures. The Verbal and Pictorial Multiple Choice Measures appeared to give consistent results in a range unaffected by "ceiling" and "floor" effects. However, as with the two other measures, there may be some question as to their effectiveness with modes of presentation that are not compatible with the format of the measures. This notion has been discussed earlier in the section entitled: The Effect of Presentation Mode (see page 27).

Further comments regarding the effectiveness of the Concept Cloze and S/E Correlation measures are necessary. The Concept Cloze test appears to have much promise as an alternative to the Standard Cloze technique. As with the Standard Cloze it is objectively constructed and scored, but unlike the standard approach, it only tests knowledge of important concepts, not knowledge associated with a combination of important concepts and trivial function words. In this study, the only difficulty with the Concept Cloze stemmed from the "ceiling effects" found with the verbal presentation of the Characteristics of Matter material. This situation could easily be alleviated by asking the subjects to fill in the appropriate key concepts in a segment of parallel text not used during the instruction but which contains the same material. This would increase the difficulty of the task over that which exists with the text material previously used during instruction.

As discussed in the presentation of the results, the S/E Correlation measure only appears to be sensitive and consistent with the Oscilloscope Operation package. Within this package this measure has substantial intercorrelations with the other dependent measures and, on the basis of the magnitude of the F ratios, it may in fact be a more sensitive indicant of performance. Although the S/E Correlation measure has promise, further exploration of its limitations, especially with varieties of instructional material, is necessary.

The intercorrelations between the dependent measures, in particular the Verbal Multiple Choice, the Pictorial Multiple Choice, and the Concept Cloze, generally fell between .60 and .70. This level of relationship is sufficient to provide some evidence of concurrent validity, but not high enough to recommend the elimination of some of the measures on the basis of redundancy. A set of measures of this type may be very useful for assessment and prescription in an instructional setting.

Summary and Conclusions

The purpose of this investigation was to explore the effects of instructional sequence on performance in an experimental context which presumably corrected some of the problems plaguing prior research in this area. In particular, the experiment was designed to accomplish the following:

(1) To assess the effectiveness of instructional sequences generated by a multidimensional scaling approach; a new approach which can objectively synthesize the views of a number of curriculum "experts",

(2) To utilize newly developed dependent measures in an attempt to provide more sensitive indicants of performance differences,

(3) To further our knowledge of the interaction of individual difference variables and sequencing,

(4) To assess the interaction of instructional sequence effects with two other educationally important variables: mode of presentation and instructional difficulty.

Although not definitive, the results of this experiment do provide evidence for the utility of the INSCAL multidimensional scaling approach in describing information structures and generating instructional sequences. Generally, the mean performances with the proximal sequence (a presumably optimal sequence generated by the multidimensional scaling approach) were higher than performances with both the original Air Force sequence, and the non-proximal sequence (a second sequence generated by multidimensional scaling using a different set of generation rules). It would be expected that performance advantages associated with the proximal sequence would be further enhanced in comparisons with newer Air Force instructional material (material in which sequence had not been heavily modified on the basis of prior instructional experience) and with larger instructional units. In any case, the INSCAL multidimensional scaling method for developing instructional sequences offers some unique advantages over the traditional subjective approaches:

(1) The INSCAL approach can combine the views of a large number of "experts" to form a single sequence. Besides providing consensual validation, this feature has the psychological advantage of involving a number of individuals in curriculum decision making.

(2) The INSCAL approach can be applied to instruction at all levels; the overall curriculum, an individual course, and/or a specific lesson.

(3) Since the INSCAL is sensitive to differences between individuals contributing individuals, it is possible to objectively select a particular instructional sequence for a specific sub-group of instructors or students.

(4) The INSCAL has the capability of providing an index of instructional complexity. Such an index would provide a strong basis for student selection and pacing.

Overall, the INSCAL multidimensional scaling approach offers advantages sufficient to warrant further research and development.

In addition to the effects of sequence, the present experiment showed consistent but small, performance differences due to mode of presentation. The Pictorial/Graphic mode led to better performance than did the Verbal mode. Since the pictorial/graphic format for the instructional material used has undergone far less research and development than the verbal format, this result is quite encouraging. Further development of the pictorial/graphic format should be undertaken and its' interaction with individual difference variables (for example, mode preference) should be assessed.

With regard to individual differences in this study, the Delta Reading Vocabulary test proved to be substantially related to performance with correlations generally ranging from .35 to .60 depending on the experimental condition. Since this measure requires very little time to administer and score it would appear to be a useful adjunct to test batteries used for student selection and prescription.

The performance differences between males and females in this experiment were substantial (the males performing at a higher level than the females). Clearly, sex should be taken into account in the design of individualized instruction, especially instruction involving scientific and/or technical content.

The Concept Close test and the S/E Correlations were two new dependent measures designed and constructed for used in this experiment. Although both of these measures contained some flaws, they appear to have sufficient potential to warrant their further investigation as indicants of successful acquisition of instructional material.

References

Dansereau, D.F., Evans, S.H., Wright, A.D., Long, G.L., Actkinson, T.A. Factors related to developing optimal instructional sequences: Phase I. AFHRL-TR-73-51 (I), Texas Christian University, Contract F41609-73-C-0023, U.S. Air Force Human Resources Laboratory, Lowry AFB, Colorado, in press, 1974.

ANNEX A

MEANS AND STANDARD DEVIATIONS FOR EACH EXPERIMENTAL CONDITION ON ALL DEPENDENT MEASURES

Performance Means and Standard on All Dependent Measures
for the Original Air Force Sequence Condition

(Proportion Correct Except for S/E Measure which
Consists of Average Correlations)

MODE OF PRESENTATION	PACKAGE DIFFICULTY	DELTA PERFORMANCE					
		HIGH			LOW		
		Measure	Mean	S.D.	Measure	Mean	S.D.
VERBAL	OSCILLOSCOPE	PMC	.590	.096	PMC	.446	.121
		VMC	.623	.108	VMC	.564	.124
		CC	.651	.225	CC	.373	.167
		S/E	.350	.172	S/E	.211	.149
		D	.768	.073	D	.544	.055
	CHARACTERISTICS OF MATTER	PMC	.907	.089	PMC	.653	.121
		VMC	.931	.077	VMC	.646	.183
		CC	.993	.017	CC	.701	.253
		S/E	.111	.027	S/E	.130	.082
		D	.876	.048	D	.603	.079
PICTORIAL/ GRAPHIC	OSCILLOSCOPE	PMC	.630	.128	PMC	.538	.126
		VMC	.643	.100	VMC	.555	.128
		CC	.647	.244	CC	.410	.192
		S/E	.340	.123	S/E	.304	.143
		D	.798	.032	D	.658	.095
	CHARACTERISTICS OF MATTER	PMC	.810	.126	PMC	.734	.195
		VMC	.838	.091	VMC	.783	.130
		CC	.916	.171	CC	.787	.200
		S/E	.154	.075	S/E	.110	.077
		D	.853	.046	D	.557	.091

N = 7 Ss Per Cell

KEY

PMC = Pictorial Multiple Choice
VMC = Verbal Multiple Choice
CC = Concept Cloze
S/E = S/E Correlations
D = Delta Reading Vocabulary

Performance Means and Standard Deviations on All Dependent Measures for the Proximal Sequence Condition

(Proportion Correct Except for S/E Measure which Consists of Average Correlations)

MODE OF PRESENTATION	PACKAGE DIFFICULTY	DELTA PERFORMANCE					
		HIGH			LOW		
		Measure	Mean	S.D.	Measure	Mean	S.D.
VERBAL	OSCILLOSCOPE	PMC	.564	.110	PMC	.487	.123
		VMC	.638	.100	VMC	.638	.216
		CC	.731	.120	CC	.387	.149
		S/E	.316	.112	S/E	.181	.132
		D	.808	.048	D	.503	.119
	CHARACTERISTICS OF MATTER	PMC	.887	.092	PMC	.663	.166
		VMC	.933	.060	VMC	.747	.107
		CC	.967	.039	CC	.713	.240
		S/E	.120	.035	S/E	.153	.048
		D	.818	.035	D	.606	.131
PICTORIAL/ GRAPHIC	OSCILLOSCOPE	PMC	.643	.139	PMC	.460	.131
		VMC	.628	.176	VMC	.554	.147
		CC	.691	.193	CC	.477	.181
		S/E	.324	.176	S/E	.197	.121
		D	.847	.072	D	.601	.088
	CHARACTERISTICS OF MATTER	PMC	.894	.069	PMC	.759	.146
		VMC	.937	.056	VMC	.763	.213
		CC	.960	.079	CC	.771	.196
		S/E	.158	.047	S/E	.113	.058
		D	.824	.062	D	.598	.058

N = 7 Ss Per Cell

KEY

PMC = Pictorial Multiple Choice
VMC = Verbal Multiple Choice
CC = Concept Cloze
S/E = S/E Correlations
D = Delta Reading Vocabulary

Performance Means and Standard Deviations on All Dependent Measures for the Non-Proximal Sequence Condition

(Proportion Correction Except for S/E Measure which Consists of Average Correlations)

MODE OF PRESENTATION	PACKAGE DIFFICULTY	DELTA PERFORMANCE					
		HIGH			LOW		
		Measure	Mean	S.D.	Measure	Mean	S.D.
VERBAL	OSCILLOSCOPE	PMC	.597	.139	PMC	.488	.157
		VMC	.623	.087	VMC	.478	.087
		CC	.641	.079	CC	.313	.168
		S/E	.307	.118	S/E	.104	.064
		D	.749	.083	D	.510	.092
	CHARACTERISTICS OF MATTER	PMC	.747	.139	PMC	.677	.106
		VMC	.758	.110	VMC	.648	.161
		CC	.813	.252	CC	.817	.090
		S/E	.143	.104	S/E	.123	.075
		D	.766	.036	D	.510	.155
PICTORIAL/ GRAPHIC	OSCILLOSCOPE	PMC	.597	.138	PMC	.538	.098
		VMC	.641	.154	VMC	.504	.054
		CC	.666	.085	CC	.546	.243
		S/E	.333	.092	S/E	.237	.162
		D	.848	.036	D	.648	.097
	CHARACTERISTICS OF MATTER	PMC	.900	.076	PMC	.701	.208
		VMC	.888	.065	VMC	.717	.222
		CC	.954	.055	CC	.747	.255
		S/E	.147	.086	S/E	.107	.091
		D	.796	.075	D	.513	.103

N = 7 Ss Per Cell

KEY

PMC = Pictorial Multiple Choice
VMC = Verbal Multiple Choice
CC = Concept Cloze
S/E = S/E Correlations
D = Delta Reading Vocabulary